Gait Modification in Healthy Individuals Following Robot-Assisted Balance Training

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BACKGROUND

People with a stroke commonly experience abnormal walking patterns (e.g., gait asymmetry), which relates to an increased risk of falls. Although diverse balance training methods have been introduced to improve walking patterns after stroke, their advantages are limited with regard to regaining gait symmetry. Thus, the development of efficient balance training approaches is necessary for gait rehabilitation following stroke. The literature shows that therapeutic approaches using the after-effect mechanism enhances functional recovery in people with neurological disorders.[1] However, no study to our knowledge has applied such a mechanism to a balance training approach. This preliminary study provides a proof of concept for our studies of RABT in people with a stroke.

PURPOSE

The purpose of this study was to identify if a robot-assisted balance training (RABT) program using the after-effect mechanism can facilitate the adaptation of a new walking pattern in healthy individuals.

METHODS

Participants

Four healthy young adults participated in this study. Each subject were randomly assigned to one of two groups receiving a RABT program (1) with standing movements (STAND) or (2) with stepping movements (STEP).

Table 1. Characteristics of Participants

Gender (M/F)	Age (year)	Height (cm)	Weight (kg)
2/2	23 ± 2.2	171.8 ± 10.2	78.8 ± 18.4

Device Descriptions

RABT device: The balance training device can apply an external perturbation using a force field to the trunk/pelvis to facilitate the modification of weight distribution during standing or stepping movements (Figure 1). Two motors, attached to the corners of a rigid standing frame, were connected to a waist belt on the participant via cables. Using feedback from force sensors attached to the cables, the motors applied a force to the lower trunk of the participant during the experiment. The combined forces from the two servomechanisms allowed a resultant force in a direction in the transverse plane that was constant or updated based on the participants motions. Two Wii balance boards (Nintendo of America Advanced Inc, WA) were used to record weight distribution during testing and to provide real time visual feedback of weight bearing during training.

GAITRite Walkway System: Gait performance was assessed using a GAITRite Walkway System (CIR Systems, Inc., PA) before and after training.

Balance Training

The subjects underwent a RABT program that consists of 120 training trials with 2-3 minutes break after every 30 trials. Each subject stood comfortably on two Wii balance boards and performed weight shifting movements (STAND group (n=1)) or stepping movements (STEP group (n=3)) following metronome beeps during training. A constant pulling force (about 30 N) was applied to the subject's trunk toward the opposite side of the target leg (see Figure 1). However, no pulling force was applied during catch trials.

Data Processing & Statistical Analysis

The subject's weight distribution during stepping movements and symmetry of gait variables (e.g., step length and double support time) during over-ground walking were assessed before and after training. Symmetry indices of spatiotemporal variables were calculated as follows.[2]

Symmetry index = [(target side – opposite side) / 0.5 (target side + opposite side)] x 100

$$\text{Symmetry index} = \left[\frac{\text{target side} - \text{opposite side}}{0.5\,(\text{target side} + \text{opposite side})}\right] \times 100$$

No statistical analysis was conducted due to the limited number of subjects.

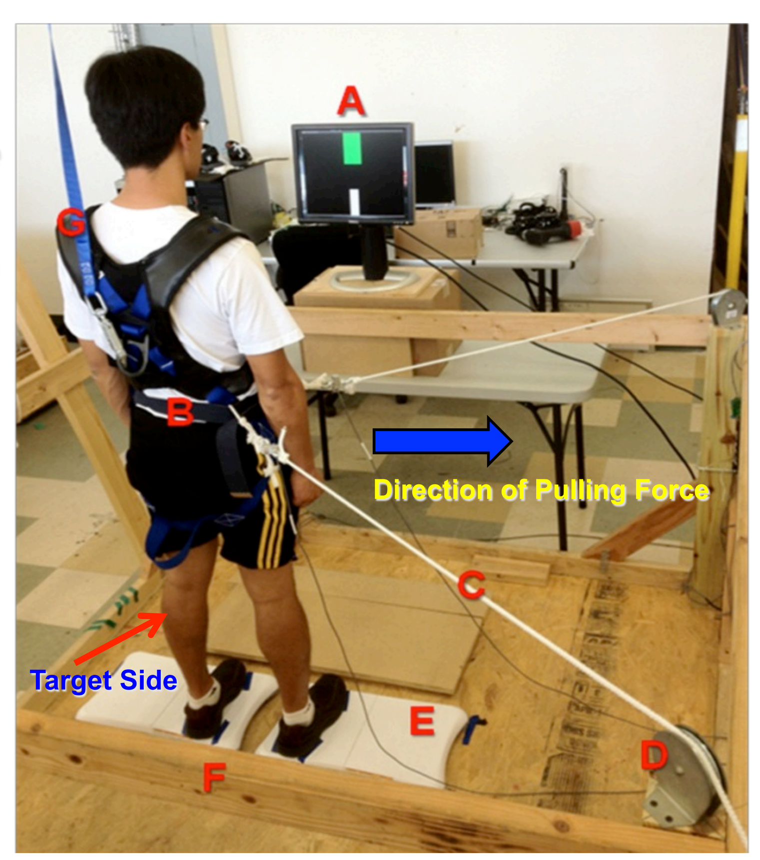

Figure 1. A prototype of robot-assisted balance training device. A: Monitor, B: Waist belt, C: Pulling cable, D: Pulley, E: Wii boards, F: Frame, and G: Safety harness

RESULTS

Change in Weight Distribution

The results showed that the subjects noticeably increased their weight shifted to the target leg during stepping movements after training (i.e., after-effect).

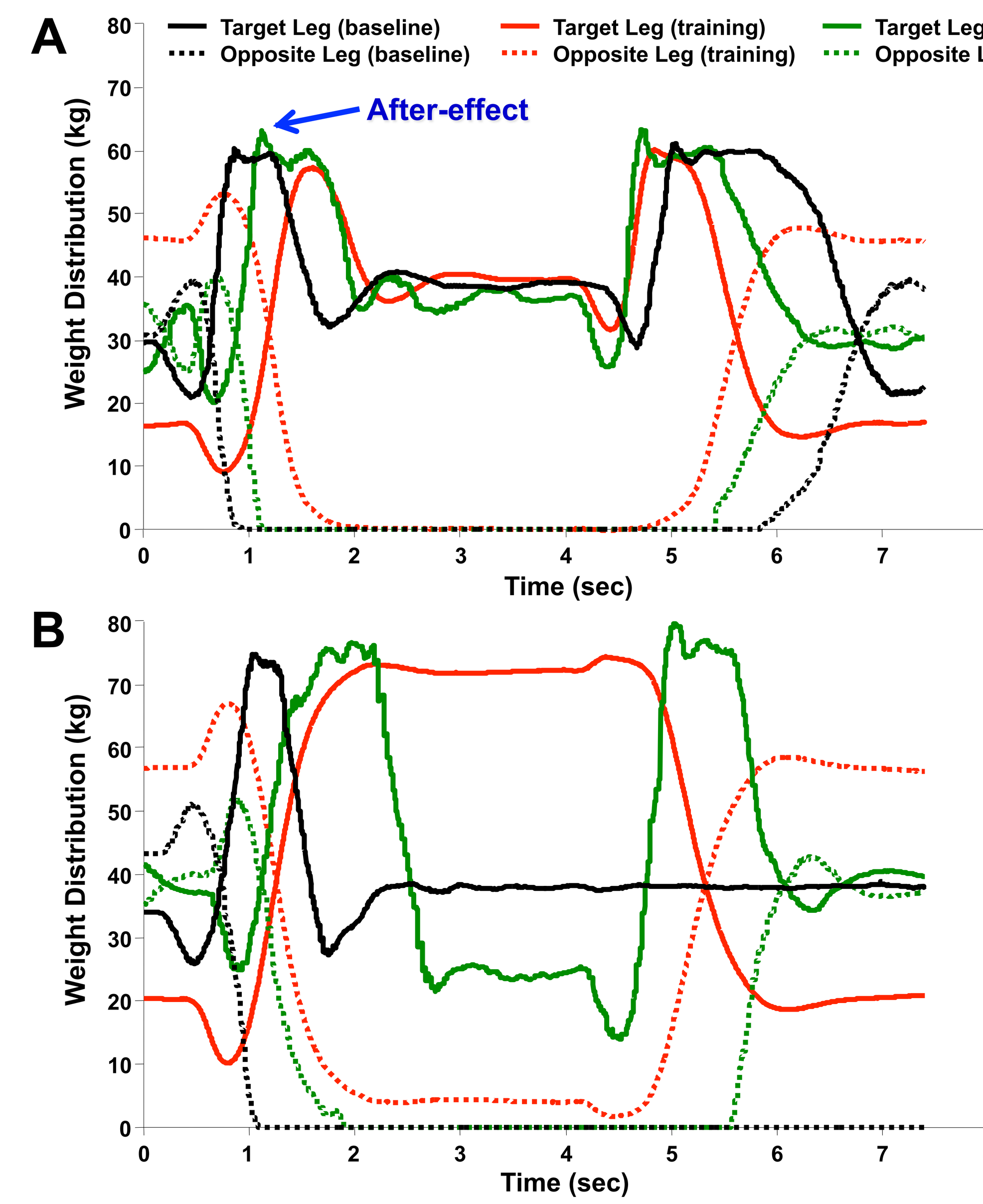

Figure 2. Changes in weight distribution over baseline (black lines) and catch tests (green lines) for a subject in the STEP group (A) and a subject in the STAND group (B). Red lines represent the average of weight distribution on each foot during training. Catch test occurred immediately after a total of 100 training trials.

Change in Step Length Symmetry

The STEP group showed noticeable changes in step length symmetry immediately after training (Figure 3) although the changes were not retained throughout the post-training test. Changes in step length symmetry after training were minimal in the STAND group.

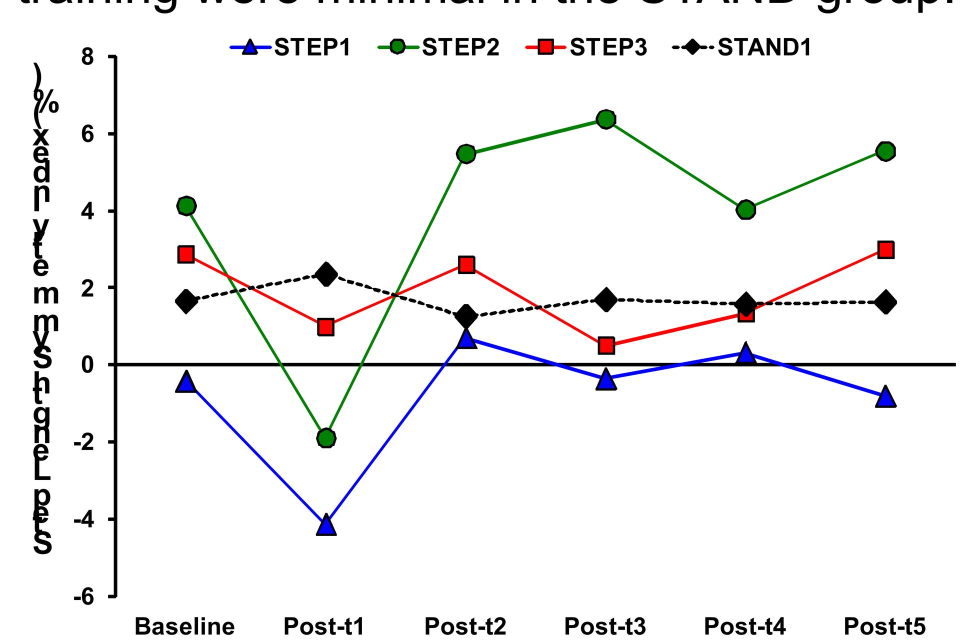

Figure 3. Changes in step length symmetry over baseline and post-training tests. STEP1-3: three subjects in the STEP group; STAND1: a subject in the STAND group; POST-t1-5: post-training trial 1-5.

Change in Double Support Time Symmetry

All subjects showed some degree of change in symmetry of double support time immediately after training (Figure 4). However, the changes were not maintained over time.

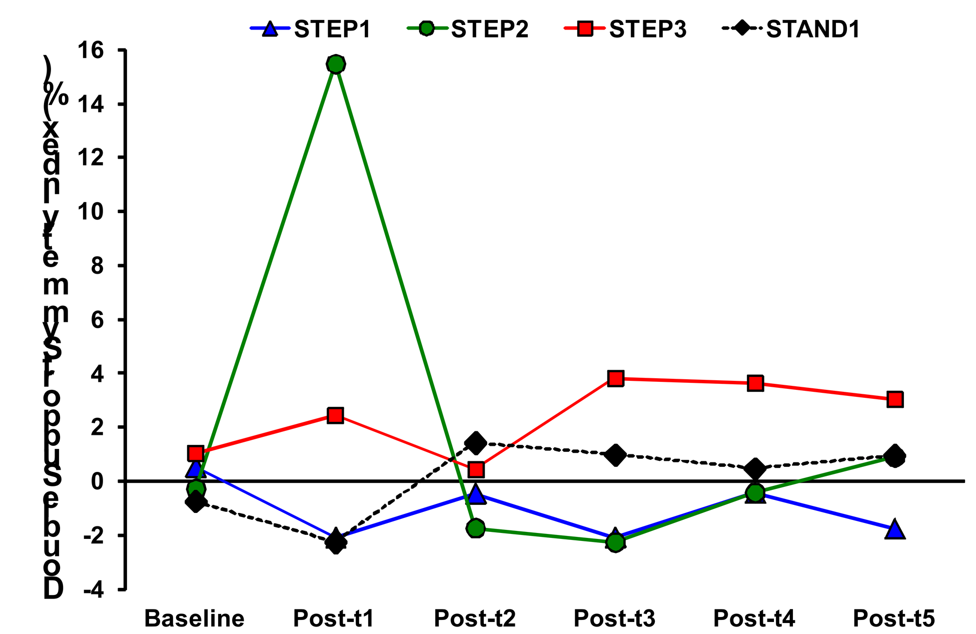

Figure 4. Changes in symmetry of double support time over baseline and post-training tests. STEP1-3: 3 subjects in the STEP group; STAND1: a subject in the STAND group; POST-t1-5: post-training trial 1-5.

SUMMARY

Healthy subjects who underwent a balance training program combining with robotic technology showed a noticeable short-term change in gait symmetry. The changes are more evident in the STEP group. Our preliminary results indicate that a RABT program using the after-effect mechanism can modify gait patterns even in healthy individuals. The results suggest that the RABT training can be used as a potential method to enhance the adaptation of a new gait pattern following stroke. Further studies are needed to identify the effect of the training program on gait symmetry in people with a stroke.

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